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Organizational information systems and biological cells: potential directions for learning?

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ORGANIZATIONAL INFORMATION SYSTEMS AND BIOLOGICAL CELLS: POTENTIAL DIRECTIONS FOR LEARNING?

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Abstract

The literature acknowledges the relationship between the study of biological systems and that of social and technological systems. However, while the relationship between the two seems to offer valuable insights, there has been little literature on how insights from the research on information behavior of cells can inform the research of organizational IS. Reflecting this literature gap, the objective of this preliminary Research-in-Progress paper is to raise an awareness of possible new insights from biological IS, as well as to demonstrate how such insights might be incorporated into organizational IS research. In this paper we suggest a few directions for progress that may be interest to IS researchers and illustrate it by exploring one specific example: information overload, which is an issue faced by both biological and organizational IS. By drawing on the similarities and differences between biological and organizational IS, potential information practices to address information overload are explored, using the concept of Information Thresholds.

Keywords: information overload; information systems; biology; cell; information thresholds

1. INTRODUCTION

The research literature acknowledges the relationship between the study of biological systems and that of social and technological systems. Similarities between the types of systems have been discussed as early as the 17th century by the philosopher Thomas Hobbes, who drew the analogy between organized society and an organism. In modern times, theories of evolution have been used in the study of economics (Nelson and Winter, 1982) and computer science (e.g. Holland, 1975; 1992).

Advances in computer-based information systems (IS) have contributed to research of biological systems, and have even spawned the research discipline of Bioinformatics. Within the IS discipline, biological systems have been used as metaphors and guidelines for new technologies and design approaches, such as interfaces (e.g. Oviatt et al 2004).

However, while the relationship between the two seems to offer valuable insights, there has been little literature on how insights from the research on information behavior of cells can inform the research of organizational IS. Reflecting this literature gap, the objective of this preliminary paper is to raise an awareness of possible new insights from research of biological IS, as well as demonstrate how such insights might be incorporated into organizational IS research.

In order to focus the discussion, the relationship between the two types of IS are discussed here by addressing a specific issue faced by both biological and organizational IS, namely Information Overload (IO) - how an organization or a cell tackles excess of information, and how the IO influences the organization or the cell's behavior. Overall, the report provides a preliminary attempt at discussing potential directions for further research taking into account the similarities between information behavior in cells and in organizations.

The structure of the report is as follows: first, a brief introduction to the concept of IO will be made; second, a brief introduction to the role and mechanism of information in cells – the basic unit in biological systems - will be outlined; third, ways in which organizational IS research into IO can benefit from insights stemming from biological IS will be discussed; and finally, general directions for further research will be suggested.

2. INFORMATION OVERLOAD IN ORGANIZATIONS

IO is an issue tackled by both organizational and biological IS. There are different views in the management and IS literature regarding the problem and its solutions, and it is possible that insights from different systems (i.e. biological) facing similar problems might be useful.

2.1. Background

IO is a widely recognized phenomenon in the management and information literature (e.g. Simon 1997; Shapiro and Varian 1999; Edmunds & Morris, 2000). It is seen as a general problem (Grise and Gallupe, 2000), that is evident in different disciplines (Eppler and Mengis, 2003), such as marketing consumer research (e.g. Owen, 1992; Kivetz and Simonson, 2000), accounting (Schick et al, 1990), and IS (Edmunds & Morris, 2000). In the research literature, IO has various synonyms such as cognitive overload (Vollmann, 1991), sensory overload (Libowski, 1975), communication overload (Meier, 1963), knowledge overload (Hunt & Newman, 1997), or information fatigue syndrome (Wurman, 2001).

According to Eppler and Mengis (2003), the term information overload refers to various organizational and individual phenomena. These are summarized in the following table 1 below:

Definitions	References
The decision maker is considered to have experienced information overload at the point where the amount of information actually integrated into the decision begins to decline. Beyond this point, the individual's decisions reflect a lesser utilization of the available information.	Chewning & Harrell (1990), Cook (1993), Griffeth et al. (1988), Schroder et al. (1967), Swain & Haka (2000)
Information overload occurs when the volume of the information supply exceeds the limited human information processing capacity. Dysfunctional effects such as stress or confusion are the result	Jacoby et al. (1974), Malhotra (1982) Meyer (1998)
Information overload occurs when the information processing requirements (information needed to complete a task) exceed the information processing capacity (the quantity of information one can integrate into the decision	Galbraith (1974), Tushman & Nadler (1978)

making process).	
Information overload occurs when the information processing demands on time to perform interactions and internal calculations exceed the supply or capacity of time available for such processing.	Schick, Gordon & Haka (1990) Tuttle, Burton (1999)
Information overload has occurred when the information-processing requirements exceed the information-processing capacity. Not only the amount of information (quantitative aspect) that has to be integrated is crucial but also the characteristics (qualitative aspect) of information.	Keller & Staelin (1987), Schneider (1987), Owen (1992), Iselin (1993)
Information overload occurs when the decision maker estimates to have to handle more information than he/she can efficiently use.	Abdel-Khalik (1973), Iselin (1993), O'Reilly (1980), Haksever & Fisher (1996)
Amount of reading matter ingested exceeds amount of energy available for digestion, surplus accumulates and is converted by stress and over-stimulation into the information overload anxiety.	Wurman (1990), Wurman (2001), Shenk (1997)

Table 1: Adapted from Eppler and Mengis, 2003

Countermeasures to information overload can be grouped into five categories (Eppler and Mengis, 2003):

- Personal factors
- Information characteristics
- Task and process parameters
- Organizational design
- IT application

While many views on how to deal with IO appear to exist, the field is said to require further research. More specifically, “a systematic methodology… to prevent or reduce information overload is still missing. Such a methodology should combine insights from various disciplines to provide effective countermeasures that can be adapted to various contexts.” (Eppler and Mengis, 2003:22). The next sections aim to point to some possible directions.

3. OVERVIEW: THE CELL – STRUCTURE AND INFORMATION FLOW

Cells are the basic unit in biological systems, and hence, in order to understand the biological IS an overview of information flow in cells is presented in this section. First, we describe how the cell communicates with its environment (how information flows) - this is illustrated in Figure 1 below. Following the general description, we present a specific example that may inform organizational information systems. In this overview, Gilrbert (2003), Alberts et al (2002), and Stryer et al (2002) are largely followed.

3.1 Information flow in biological systems

Cells are the basic units of life. Examples include single cellular organisms as bacteria, yeast, plasmodium (the malaria parasite), and cells in multi-cellular organisms as neurons, blood cells and muscle cells, to name just a few. Common to all types of cells is their ability to communicate with their environment, in other words to receive, transmit and interpret information present in their environment and respond accordingly. We first draw a simplistic picture of how information (signals) is transduced (communicated) and how environmental information is interpreted by the cell (see Figure 1 below).

Cells are separated from their environment by a barrier called the cell membrane. In order for cells to communicate with their environment, information present outside the cell needs to traverse this barrier. One frequently used way is through so-called receptor proteins. These receptors span the membrane barrier thus having an extra-cellular part and an intracellular part. Certain receptors are specific for a certain kind of information. The physical interaction of the information (signal) with the external part of the receptor causes a physical change within the receptor leading to its activation. Subsequently, the intracellular part of the receptor communicates the presence of the external information to messenger components/molecules/proteins inside the cell. This information (signal) transmission is achieved, in many cases, by activation/modification of downstream messenger components. The ultimate outcome of this information flow (or signal transduction) is a change in the character of the cell. This can be a very subtle change (e.g. the cell may increase its level of production of a certain molecule) or as profound as changing the identity of the cell (an unspecialized cell may become a neuron or muscle cell).

One principal response to information relay is the expression of genes. Genes can be viewed as plans from which to build all/most of the necessary components/elements of a cell. Each cell contains all genes (plans) to build any component of a whole organism. However, in an individual cell not all genes are being expressed (for example, of the approximately 30,000 genes of the human genome only a subset is expressed in a given cell. Two different cells are very unlikely to express the exact same set of genes). The consequence of relaying information from the environment to the nucleus (the place within the cell where genes are kept) is the expression of a certain set of genes, depending on the specific information that is being transduced. These genes are then being translated into active components that serve specific functions. For example, as a response to pathogen invasion (such as infection with a bacterial disease), cells of the immune system respond to the presence of those pathogens (information about the presence of pathogens) by the expression of genes that encode components, called antibodies, directed against the invaders.

In summary, information in the environment of a cell is transduced to the nucleus where a specific collection of genes is expressed as a consequence. The products of these genes serve functions that are required for the cell within this changed environment.

3.2 Information flow: the information overload context

The following are two specific questions that seem to be relevant to the comparison of organizational and biological information systems. They address issues of quantitative and qualitative changes in the information flow in the cell. The first questions concerns how an organism at the level of its basic unit, deals with the input of different information qualities and how does it give preference to the more important one. As an example we outline how two contrasting kinds of information, encoded by the signaling molecules Adrenalin and Insulin, affect the response of a cell that is exposed to both of them. The second question concerns how a cell deals with increasing concentration of the same kind of information. Here, concentration related responses (also called threshold responses), as they are common in developing embryonic tissues, provide the example.

Adrenalin versus Insulin:

Most humans feel sleepy after a big meal, which is a physiological response to the intake of nutrition and the on-setting digestion. The intake of food causes the release and spreading throughout the entire organism of a signaling molecule, Insulin that informs cells everywhere within the organism to adopt states that support the digestion of the in-taken nutrition. For example, the distribution of blood in our digesting body is, compared to a non-resting state, mainly distributed in those organs that are involved in digestion as for example the gut. In contrast, our muscles are in a relaxed state. If in such a situation we suddenly encounter danger our body needs to react accordingly to save our life. As seen above, a signaling molecule, this time informing the body about the potential danger, is spread throughout the organism. At this time, cells within the organism are exposed to two contrasting types of information, one telling it to relax and to digest, and the other to react fast (for example, to run away from a dangerous animal). Obviously, information about the potential danger is more important. Both kinds of information are communicated to the interior of the cell by means of receptor molecules (see above) and each receptor transmits its information by means of distinct intracellular messenger molecules. Those messengers that are activated by dangerous information not only activate adequate responses but, importantly, block any further information transmission by those messengers that were activated by food in-take. In summary, a cell is able to distinguish between qualitatively different types of information and gives priority to one. This can be accomplished, as seen in this particular example, by intracellular competition between messengers.

Threshold responses:

In many developing tissues cells respond differently to increasing concentrations of the same signaling molecule. This is an important process because it is used to pattern a tissue; that is to make sure a certain kind of cell-type forms in a defined, and not random, location. For example, not only needs a naïve cell to be told to become a neuron, but as important is to place it correctly so that a functioning organ can form (for example brain or spinal cord).

In some cases this is accomplished by providing a localized source of an information molecule. It is evident that cells that are further away from this source receive a smaller concentration of this same information than does a cell that is close to this source. Both cells, those that are exposed to high, and those that are exposed to low, concentrations, use the same information transmission pathway. The same kind of receptor and messenger is activated by this information. However, there is one important difference between the information transmission within in these two otherwise equal cells, that is the extent of messenger activation. The amount of messenger determines what kinds of genes are being expressed. For example, a large number of messengers (reflecting a large amount of one kind of information) may cause the expression of neural genes, whereas a small number of the same messenger may lead to the expression of muscle genes. In other words, cells respond to information below a certain threshold by the expression of muscle genes, and above this threshold by the expression of neural genes.

In summary, cells are able to respond differentially to increasing concentrations of information by employing thresholds of sensitivity to the level of information.

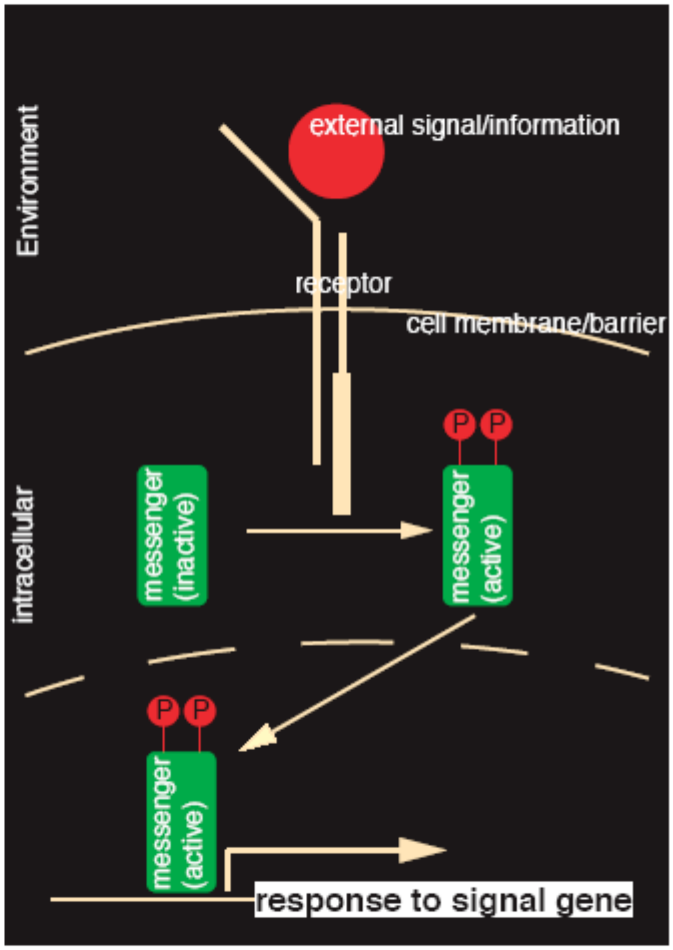

Figure 1. The cell: Information flow

4. DISCUSSION AND FURTHER RESEARCH

There appear to be similarities between the characteristics of IO in organizational IS and biological IS – for example, IO appears to reduce the significance of new information to the point where it is not internalized by the system (be it a cell or an organization). Thus, we would like to explore possible extensions to existing organizational IS approaches to IO, based on insights from biological research – as outlined above.

One such possible direction is in the creation of information thresholds: according to findings in biology, cells often express different qualities – i.e. the character of the cell changes (=change in gene expression = eye cell → hand cell) depending on information quantity received. Thus, when the information quantity reaches certain thresholds, there is a new gene expression or different gene expression altogether. Viewed within an organizational context, an Information Threshold approach to dealing with IO might call for pre planning and structuring of possible changes in the organization's behavior and structure as a response to new information to be received. More specifically, it calls for in-advance development of scenarios for potential inflow of information, and the ensuing changes the organizations might make. While such processes and scenario based scripts do exist today – notably in cases of emergency situations – it may be worth exploring the usefulness of such an approach as part of non-emergency strategic planning. In terms of IO, the concept of information thresholds seems to bridge the countermeasures of Information Characteristics, Task and Process Parameters and Organizational Design (see Eppler and Mengis's categorization above), and provide a useful and possibly new way of handling IO.

The concept of information thresholds, and of information overload in general, for that matter, provides just one illustration of the potential directions learning from biological systems may take, and more work is needed in order to articulate and develop further the case for biologically informed organizational IS research. Thus, it is suggested here that future research may focus on other directions that capitalize on the similarities between the two types of IS, such as the following:

- The effect of changes in the content and quantity of external information on changes in the characteristics of the organization: in the cell, changes in incoming information changes the cell's behavior, and in some cases, its function (what it does). The mechanism of this might provide insights for IS researchers studying the role of information and IS as a factor in organizations' strategy and behavior.
- Internal and external information sharing mechanisms – in cells and in organizations.
- The role of information in facilitating specialization and outsourcing of operational functions in the course of evolutionary processes - in both organizational and biological systems.

Overall, this Research-in-Progress paper serves as a preliminary call for further exploration of the potential for the IS discipline to learn from information behavior of cells. Such exploration, it seems, is interdisciplinary in nature, and requires collaboration between researchers from both the biology and IS areas. We hope that such joint work could potentially lead to new ways of thinking about information behavior and use in organizations, and consequently, new perspectives from which IS theory and practice could benefit.

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